PERFORMANCE OF FINITE COVER METHOD FOR PHYSICALLY AND GEOMETRICALLY NONLINEAR PROBLEMS

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We examine the performance of the finite cover method (FCM), which can be regarded as one of the generalized analysis methods or a sort of mesh-free methods, for physically and geometrically nonlinear problems. After presenting the approximation concept of the FCM, we conduct several numerical experiments to assess the capabilities of the FCM in the framework of the finite element method (FEM). Then the formulation is extended to the structural analyses with homogeneous and heterogeneous elastic-plastic materials with small strains and hyperelastic ones with finite strains.

First, we introduce the FCM, which evolved out of the manifold method (MM) [1], as an alternative of the generalizations of the FEM and briefly review the features as an analysis method with reference to our recent development [2]. The concept of mathematical and physical covers for approximating functions are presented and the elements of the FCM is defined as contrasted with those of the FEM. Also, we discuss the eligibility of the FCM for a generalized method by emphasizing the role played by the weight function with the partition-of-unity properties. The problem under consideration here essentially involves the discontinuities in strains, and possibly in displacements. This actually motivates us to extend the FCM to physical and geometrical nonlinearilties.

Next, prior to nonlinear analyses, we examine the basic approximation properties of the FCM in the context of the FE analyses for linear elastostatics. Since the elements of the FCM are almost the same meaning of the FEM, the standard performance tests for finite elements are conducted on the elements in the FCM. Also, the rational approach with the augmented Lagrangian method is proposed for the treatment of material interfaces or mesh boundaries in the FCM (just as mortar finite elements) and its performance is studied in comparison with the penalty method. Those numerical results illustrate the capabilities of the FCM, which are equivalent to and in some cases predominant over those of the FEM.

Finally, we extend the FCM for physically and geometrically nonlinear problems. Since the approximation concept and techniques of the FCM are almost the same as those of the FEM, the material nonlinearities and the large deformation kinematics are easily incorporated into the FCM. For the former nonlinearity, we focus our attention to homogeneous and heterogeneous elastic-plastic materials with small strains. On the other hand, the standard weak formulation is simply provided in the Lagrangian frame and finite deformation kinematics is introduced to the standard finite cover approximation. Representative numerical examples for hyperelastic bodies demonstrate not only the preferable analogies and distinctions with the FEM, but also the limitation by the Lagrangian formulation. Thus, we also provide the FCM algorithm that enjoys the Eulerian description and confirm the novel capability as a meshfree method.

References

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